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TRINEXAPAC-ETHYL APPLICATION ENHANCED PHYSIOLOGICAL PERFORMANCE OF *PRUNUS PERSICA* (L.) BATSCH. UNDER DROUGHT CONDITIONS

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Abstract

The development of water-wise cultivation systems is critical for the horticulture industry. The morphological and physiological performance of one-year-old container grown seedlings of three peach cultivars (Cresthaven, Vivid and Harson) under two deficit irrigation regimes (70 and 50% of field capacity) for 8 weeks coupled with trinexapac-ethyl (TE) foliar sprays at 0.25, 0.5 and 1 ml/l (11.3%) was evaluated. There were significant reductions in leaf number and leaf area, plant dry weight, root dry weight, plant height, photosynthetic rate, stomatal conductance, transpiration rate, leaf midday water potential and relative water content and the evapotranspiration rate in the three cultivars during deficit irrigation levels of 70 and 50%. Compared to untreated plants, TE sprays at 0.5 and 1 ml/l significantly enhanced peach cultivars performance by means of increased leaf number and area, plant dry weights, photosynthetic rate, stomatal conductance, transpiration rate and leaf midday water potential and relative water content.

Introduction

Peach (*Prunus persica* (L.) Batsch) belongs to Rosaceae and, from economic perspective, it is highly ranked among global fruit crops production with over 10 million tons in 2012 (FAOSTAT, 2015). However, drought and salinity stresses affect negatively plant root shoot and fruit growth of peach and different crops (Turkyilmaz 2012, Thakur and Singh 2012, Rahmati *et al.* 2015). Plant growth and development are regulated internally by phytohormones and the exogenous application of growth regulators that might enhance some plants performance under deficit irrigation conditions (Elansary and Salem 2015, Krishnan and Merewitz 2015). trinexapac-ethyl (TE) is derived from cyclohexanecarboxylate and commercially approved as synthetic growth regulator used for the control of growth of diverse crops including cereals (Rademacher and Bucci 2002). A few investigations indicated that TE sprays might enhance the drought and salinity of turfgrasses (Arghavani *et al.* 2012, Elansary and Yessoufou 2015) by reducing water depletion and increasing osmotic adjustment leading to increased drought resistance. TE application might enhance fruit trees morphological and physiological performance under deficit irrigation but this has never been explored. The aim of the present research was to evaluate the morphological and physiological responses of three peach cultivars (Cresthaven, Vivid and Harson) which are commonly grown in Canada grafted on Bailey rootstock and submitted to deficit irrigation to simulate restricted water access. During deficit irrigation episodes, TE sprays were applied at different doses to evaluate the stress tolerance enhancing effect and the interactions among irrigation levels, TE sprays and cultivars. The objective was to identify the suitable doses and irrigations conditions that may enhance the production of peach trees in nurseries under deficit irrigation conditions. This work may improve our knowledge of peach trees

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responses to exogenous growth enhancers during deficit irrigation and drought periods and may improve the performance of peach trees in nursery production and help in alleviating drought effects on trees.

Materials and Methods

Three cultivars of peach trees (Cresthaven, Vivid and Harson) grafted on Bailey rootstock were obtained in April of two successive years (2014 and 2015) from commercial nurseries in 2.6l pots containing black peat and perlite (1 : 1 v/v) as growing media. The plants were identified by Dr. H. Elansary and vouchered at the Biodiversity Institute of Ontario (No. HOS1010-1016). Trees were transplanted into 5-l pots, which are common in growing peach trees, in a controlled greenhouse conditions in Guelph, Ontario, Canada (43° 30′ 18.24″ N 80° 22′ 15.86″ W) in each year. Vivid and Harson are mid-season cultivars while Cresthaven is a late season cultivar and the plants were one-year-old when obtained. Each pot contained one plant with a growing media of Sunshine Mix # 5 (SunGro Horticulture Canada Ltd., Seba Beach, Canada). In both years, uniform plants were selected for the experiment that has the heights of 56, 60, and 53 cm for Cresthaven, Vivid and Harson, respectively. The plants were supplemented with Osmocote Plus (14 : 13 : 13 N, P, K + microelements) (2 g/l media) and the temperatures ranged between 23.1 and 28.9°C. The mean relative humidity ranged between 55 and 62%, the photosynthetically active radiation was 1000 µmol/m^2/sec at 10.00 a.m. and the plants were maintained at 12 hrs light conditions for one month which is the normal day length. The experiments were repeated twice during April of the years of 2014 and 2015. Plants were watered daily by drip irrigation for the full pot field capacity which was determined by the gravimetric method before starting the irrigation levels and on daily basis during the experiment. Initially, 8 plants were irrigated with a known amount of water to saturate the soil. The pots were left to drain for 40 minutes, the drained volume was quantified, and the difference between the irrigation and drained water was considered as the pot substrate field capacity. In the control of each species, the plants were subjected to the three irrigation levels of 100, 70 and 50% of pot capacity and trinexapac-ethyl (TE) treatments were replaced by water. During the days of the treatments, the volume of water required to achieve the pot field capacity represented the consumption of water during the previous day. In the TE-treated plants, all cultivars were subjected to irrigation levels of 100, 70 and 50% of control pot capacity (100%) for 8 weeks and three doses of foliar biweekly applications of TE (Primo Maxx®, Syngenta CA, Inc.; a.i. 11.3% TE) of 0.1, 0.2, and 0.3 l/ha [(0.25, 0.5 and 1 ml/l]. Irrigation levels simulated well-watering conditions (100%), light deficit irrigation (70%) and moderate deficit irrigation (50%). TE treatments started 2 weeks before initiating water regimes and continued during the experiment. The duration of watering was used to control the amount of water supplied (201-570 ml per pot). Peach cultivars were grouped into three repetitions (n = 3) and 5 plants per treatment, totaling 135 plants per cultivar distributed on three blocks. The plants were randomly arranged in rows contained combinations of cultivar × irrigation treatment in each block. Following 8 weeks of deficit irrigation and observing deficit irrigation signs on control plants, the plants were harvested and the substrate was washed off the roots. Leaf numbers (LN) were calculated for each plant, also leaf area (LA) was measured using (Delta-T Devices Ltd., Cambridge, UK). Plant total dry weight (PDW) and root dry weight (RDW) were determined by drying in the oven at 70°C to reach constant weight. Plant heights (PH) were recorded in cm at the end of the experiment. Measurements of net photosynthetic rate (A), transpiration rate (E) and stomatal conductance (g_s) were performed using the (ADC, LCi, Bioscientific Ltd., Hoddesdon, UK), in a clear sunny conditions between 10 a.m. and 12 p.m. using fully expanded leaves in the middle of the canopy on a weekly basis (5 measurements for each treatment during deficit irrigation episode). The evapotranspiration rate (ET) was determined based on the daily change of

ET in three representative of each treatment by watering with enough water and leaving to dry for 2 hrs, then weighing each representative, reweighing every 24 hrs and the daily changes in weight represent the daily ET in each treatment. The leaves midday water potential (ψ) and the midday relative water content (RWC) were determined in 3 plants per treatment at the end of the experiment between 12:00 and 2:00 (solar time). Midday water potential of leaves were calculated according to Elansary and Salem (2015) using a pressure chamber (PMS Model 1505D, PMS Instrument Company, Oregon, USA). A split-split plot experimental design was employed with irrigation levels being the main plot, TE treatments the subplot and cultivars the sub-subplots. Experiments data of the years 2014 and 2015 were subjected to the analysis of variance (ANOVA) as implemented in (SPSS, V.22 PASW). We found no significant differences between the two years, consequently the data were pooled together for the analyses of irrigation levels, TE sprays and cultivars effects using the ANOVA of the GLM procedure in the SPSS software package (SPSS v. 18 PASW).

Results and Discussion

In all control plants, there were reductions in leaf number and leaf area, plant and root dry weights, and plant height following the deficit irrigation of 70 and 50% (Table 1). Peach cultivars had different responses to TE sprays and irrigation levels. However, under deficit irrigation of 70 and 50%, TE sprays significantly increase leaf number and area, root dry weight and slightly plant height, but had no effect on plant dry weight in most cases. Cresthaven had different morphological responses to TE doses. Under well watering conditions, TE doses showed no significant differences in all morphological parameters. However, deficit irrigation and TE doses of 0.2 and 0.3 l/ha significantly increased leaf number and area and root dry weight compared to the 0.1 l/ha dose. TE dose of 0.3 l/ha yielded the highest leaf number, leaf area, and plant and root dry weights. Vivid control plants showed similar morphological performance as Cresthaven (Table 1). In Harson peach plants grown under well watering conditions, we found no significant effect of TE sprays on leaf number and area, plant dry weight and plant height. However, root dry weight increased significantly following TE sprays from 21.2 g/plant in the control to 22.3 g /plant in plant subjected to 0.3 l/ha TE. Under deficit irrigation (70%) in Harson peach plants, TE sprays with 0.2 and 0.3 l/ha significantly increased leaf number and area, plant dry weight and root dry weight but had no significant effects on plant height. A similar reduction in leaf number and area following TE sprays were described in other plants such as *Brachiaria brizantha* (Fialho *et al.* 2009), *Ocimum basilicum* (Elansary 2015), ornamental shrubs (Elansary and Salem 2015). This effect could be attributed to the inhibition of the formation of GA1 from GA20 as well as blocking the conversion of GA1 to GA8 (Rademacher 2000) and consequently, TE application inhibits cell elongation, suppresses the vegetative growth and affects the hormonal balance in plants (Krishnan and Merewitz 2015). In control plants, A, E and g_s values were reduced proportionally after 8 weeks of deficit irrigation (70 and 50%). Peach cultivars showed variation in A, E, and g_s values as physiological response to deficit irrigation and TE sprays treatments (Table 2). In Cresthaven, under 70% container capacity, different doses of TE sprays caused significant increases in A, E and g_s values compared to untreated plants. When irrigation level was lowered to 50%, TE sprays of 0.1 l/ha showed lower increases in gas exchange parameters than the 0.2 l/ha TE dose. Vivid cultivar has similar performance as Cresthaven. In Harson peach, there were reductions in gas exchange parameters in control plants following deficit irrigation treatments as seen before in other cultivars. The decreases in gas exchange parameters were lessened following TE treatments of 0.2 and 0.3 l/ha specifically. Also, TE treatment of 0.1 l/ha had no effect on gas exchange parameters in plants undergoing deficit irrigation of 70% container capacity. These responses are described as drought avoidance mechanism (Franco *et al.* 2006) and similar reductions in A, E and

Table 1. Mean values of morphological parameters at the end of experiment (8th week) under different irrigation levels (100, 70 and 50% of container capacity) and TE treatments (0.1, 0.2, and 0.3 l/ha) on Cresthaven, Vivid, and Harson leaf number (leaf/plant), leaf area (cm^2/plant), plant dry weight (g/plant), root dry weight (g/plant), plant height (cm) at the end of the experiment. Control plants were used in each irrigation level × TE treatment (Con1, 2 and 3).

		Leaf number			Leaf area			Plant dry weight			Root dry weight			Plant height		
		Crest.	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson	Crest.	Vivid	Harson
100%	Con1	402a	345a	291a	9246a	7706a	6556a	132.8a	109.6a	100.8a	30.6a	21.9a	21.2b	99.1a	93.0a	90.6a
	0.1 TE	390b	337b	292a	8991b	7534ab	6598a	131a	108.2a	101.8a	29.3ab	21.3b	21.7ab	98.5a	93.2a	90.3a
	0.2 TE	388b	334b	298a	8877b	7395b	6652a	130.2a	107.6a	102.2a	28.6b	21.3b	22.3a	97.8a	92.6a	89.8a
	0.3 TE	390b	337b	289a	9000b	7534ab	6544a	130.4a	107.8a	100.0a	29.1ab	21.2b	22.0ab	98.0a	91.8a	90.8a
70%	Con2	305b	250b	195b	6741b	5344b	4246b	102.2b	86.0b	74.6b	25.6c	20.6d	16.4d	89.8a	82.4a	78.0a
	0.1 TE	307b	252b	204b	6754b	5361b	4397b	102.1b	86.4ab	76.6ab	25.6c	21.6c	17.6c	88.0ab	80.0ab	77.2a
	0.2 TE	322a	268a	220a	7055a	5651a	4735a	102.3b	89.0ab	79.6a	26.6b	24.0b	19.1b	86.4ab	80.0ab	76.6a
	0.3 TE	327a	274a	226a	7135a	5731a	4843a	105.2a	90.6a	80.8a	27.7a	24.9a	20.2a	85.8b	79.0b	76.2a
50%	Con3	214c	160b	140a	4533c	3274c	2900a	73.4a	68.6a	55.7a	19.8b	17.1c	13.5ab	65.4a	65.4a	66.8a
	0.1 TE	225b	176ab	132ab	4721b	3531b	2722ab	74.2a	70.7a	55.7a	21.5a	19.1b	14.5a	64.0a	63.6a	66.4a
	0.2 TE	234a	180ab	130ab	4913a	3742a	2669ab	75.4a	72.7a	55.7a	22.0a	21.1a	13.9ab	65.4a	63.0a	64.2a
	0.3 TE	230ab	182a	124b	4827ab	3730a	2537b	75a	73.5a	53.8a	22.1a	21.9a	13.4b	63.6a	62.6b	64.4a

*Means followed by different letters within a column indicate significant differences between treatments based on LSD test ($p = 0.05$).

Table 2. Mean values of physiological parameters at the end of experiment (8th week) under different irrigation levels (100, 70 and 50% of container capacity) and TE treatments (0.1, 0.2 and 0.3lha) on Cresthaven, Vivid and Harson photosynthetic rate (µmolCO_2/m^2/sec), transpiration rate (µmol/m^2/sec), stomatal conductance (µmol/m^2/s), leaf midday water potential (MPa), leaf relative water content (%), and evapotranspiration (ml/d/pl). Control plants were used in each irrigation level × TE treatment (Con1, 2 and 3).

		Photosynthetic rate			Transpiration rate			Stomatal conductance			Leaf midday water potential			Leaf relative water content			Evapotranspiration		
		Crest	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson	Crest	Vivid	Harson
100%	Con1	8.5a	7.70a	8.14a	4.44a	4.22a	4.30a	157.4a	138ab	147ab	–0.81a	–0.75ab	–0.78a	81.8a	75.6a	77.9a	548a	460a	510a
	0.1 TE	8.6a	7.62a	8.14a	4.58a	4.16a	4.34a	162.2a	130ab	149a	–0.75a	–0.78ab	–0.82a	83.7a	72.4a	80a	536a	464a	518a
	0.2 TE	8.8a	7.78a	8.06a	4.52a	4.24a	4.26a	163.6a	142a	144b	–0.82a	–0.71a	–0.82a	84.4a	78.6a	76.6a	528a	448a	506a
	0.3 TE	8.8a	7.58a	8.20a	4.5a	4.12a	4.30a	162.2a	134b	148ab	–0.78a	–0.81b	–0.85a	84.4a	75.5a	78.6a	524a	472a	526a
70%	Con2	7.2b	6.76b	6.92b	3.82b	3.56b	3.72b	125.4b	93b	102b	–1.20b	–1.14b	–1.24b	70.5b	62.6b	66.1b	396a	309a	346a
	0.1 TE	7.8ab	6.9ab	6.96b	4.08ab	3.8ab	3.76ab	130.6ab	99ab	105ab	–1.12ab	–1.06ab	–1.18ab	74.9ab	66.6ab	69.2ab	364b	294ab	337ab
	0.2 TE	7.9ab	718ab	7.26a	4.18ab	3.98a	3.80ab	134.8ab	105ab	109ab	–1.08ab	–0.98ab	–1.04ab	77.6ab	69.6a	71.4ab	356b	282b	317ab
	0.3 TE	8.0a	7.34a	7.28a	4.22a	3.99a	3.86a	140.4a	111a	111a	–0.96a	–0.92a	–0.91a	78.9a	70.8a	74.2a	347b	272b	310b
50%	Con3	5.4b	4.62a	4.34a	2.9b	2.72b	2.92a	91.9b	73.2b	65.5a	–1.60a	–1.54b	–1.66a	59.2b	49.3b	54.2a	301a	202a	266a
	0.1 TE	5.7ab	4.88a	4.20a	3.04ab	2.88ab	2.86a	94.4ab	77.2ab	59.7ab	–1.52a	–1.44ab	–1.76a	62.3ab	53.1ab	50.3ab	282ab	192ab	261a
	0.2 TE	6.1ab	5.16a	4.14a	3.16ab	3.02a	2.84a	100.9a	79ab	56.3ab	–1.44a	–1.32a	–1.86a	67.5a	57.6ab	48.9ab	260b	186ab	269a
	0.3 TE	6.0a	5.12a	4.12a	3.12a	3.08a	2.82a	98.7ab	81a	55.4b	–1.46a	–1.30a	–1.94a	64.5ab	59.6a	46.1b	263b	181b	274a

*Means followed by different letters within a column in irrigation level indicate significant differences between treatments based on LSD test (p = 0.05).

g_s were described in fruit trees following deficit irrigation and water stress only (Jiménez *et al.* 2013, Rahmati *et al.* 2015). The increases in the photosynthetic rates following TE sprays might be explained by the protective effects of TE on the photosynthetic activity (Rajasekaran and Blake 1999). Also, significant increases in the photosynthetic rates that enhanced the drought avoidance mechanism following TE sprays were described in a few studies such as in ornamental shrubs (Elansary and Salem 2015), herbs (Elansary 2015) and turfgrasses (Elansary and Yessoufou 2015). Peach cultivars showed variation in their ψ, RWC and ET values in response to TE treatments under well watering and deficit irrigation conditions. In general, there were reductions in ψ, RWC and ET values following deficit irrigation in control plants. In contrast, Cresthaven plants showed no significant differences in ψ, RWC and ET values among control plants and TE-treated plants under well watering conditions. However, when reducing the irrigations level to 70%, there were significant differences in ψ, RWC and ET among control and TE-treated plants. The highest increase in ψ, RWC was from –1.2 to –0.96 MPa and from 70.5 to 78.9%, respectively in plants treated with 0.3 l/haTE. ET values were lowered after TE treatment with 0.3 l/ha from 396 to 347 ml/d/pl. Under 50% irrigation deficiency, there were significant effects of TE on RWC and ET. Vivid plants, grown under well watering conditions, showed increases in ψ and RWC, but these increases were only significant in the former. Under 70% watering conditions, TE sprays had significant effects on ψ, RWC and ET values. TE 0.3 l/ha treatment recorded the highest values of ψ and RWC and the lowest values of ET. Interestingly, increasing irrigation deficiency to 50% coupled with TE treatments, showed significant variation in ψ and RWC values among treatments. The highest values were found in TE-treated plants with 0.2 and 0.3 l/ha. Further, ET values were the lowest in plants treated with 0.3l/ha TE. Harson plants did not show significant variations among control and TE-treated plants under well watering conditions. Under 70% deficit irrigation conditions, there were significant increases in ψ and RWC values following TE treatments. In addition, the reduction in ET values was significant in all TE doses. Under 50% irrigation levels, we found no significant effects of TE on ψ and ET. The reductions in leaf water potential and relative water content following deficit irrigation and water stress conditions in this study are in line with previous investigations on peach trees (Rahmati *et al.* 2015) and rootstocks (Jiménez *et al.* 2013). The reduction in RWC may occur due to the reduction in the stomatal conductance (Elansary and Salem 2015). TE sprays significantly enhanced ψ values in Cresthaven and Harson under the 70% deficit irrigation and Vivid under the 70 and 50% deficit irrigation. This might be explained by the protective effects of TE on the photosynthetic apparatus during drought conditions (Rajasekaran and Blake 1999, Elansary and Salem 2015). The ET values following deficit irrigation conditions were found which is in agreement with previous studies on peach trees (Girona *et al.* 2002, Rahmati *et al.* 2015). In addition, the ET reductions match those found in the stomatal conductance and the photosynthetic rates in the three cultivars, are in agreement with previous investigation on the effects of deficit irrigation on peach trees (Girona *et al.* 2002).

TE foliar sprays at 0.2 and 0.3l /ha significantly enhanced the performance of all the cultivars under 70% deficit irrigation and sufficiently enhanced the overall plant performance in Cresthaven and Vivid during 50% deficit irrigation. These enhancements were detected in leaf gas exchange parameters, leaf water potential, and relative water content, which are proven to play a pivotal role in peach trees water relations.

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